Peeling Property of Resist Pattern in Water Analyzed by Atomic Force Microscope

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1. Introduction
Recently, in a liquid environment, the improvement of the adhesion strength of the resist micropattern has been recognized as a serious problem that need to be solved. A cause of this phenomenon is Laplace force due to the surface tension of the liquid remaining between the line patterns. In this regard, the present authors have already proposed the novel principle for analyzing resist pattern adhesion and cohesion, that is, DPAT (direct peeling with atomic force microscope (AFM) tip) method. In this study, resist pattern adhesion in deionized (DI) water is characterized by using the AFM. The peeling property of resist pattern in liquid environment is studied on the comparison with that in dry air. Understanding the peeling properties of resist micropattern is of crucial importance for the development of microelectronic device.

2. Experiment
A chemically amplified positive resist consisting of polyhydroxystyrene with acid labile blocking groups and photoacid generators was used. The blocking group was tert-butoxy carbonyl (t-BOC). The photoacid generator was trifluoromethanesulfonic acid. Silane-coupling treatment with HMDS was performed prior to spin-coating of the resist film. The resist film of 480 nm thickness was coated onto the Si(100) substrates by the spin method. Pre-baking was carried out at 90 °C for 105 s. Subsequently, the resist patterns were developed by dipping into tetramethylammoniumhydroxide (TMAH) 2.38 % aqueous solution for 90 s and were subsequently rinsed in the deionized water. Finally, these patterns were dried by the spin method.

A commercially available AFM, integrated with a micro cantilever tip was used for the pattern peel investigation. The length, width and thickness of the cantilever made of silicon nitride thin film was 240, 30 and 4 μm, respectively. The tip was made of Si single crystal by photolithography technique. The radius of curvature of the tip apex is approximately 8 nm. The apex angle of the tetrahedral tip was approximately 15 degree. The torsion and deflection spring constants of the cantilever were 600 and 2 N/m, respectively. The cantilever torsion, brought out by contacting a resist pattern, was detected using a laser reflection system. Figure 1 shows a schematic explanation of the peeling procedure accompanying with the detection forces due to the cantilever displacement. (i): Prior to the pattern peel investigation, the resist pattern was imaged by the AFM in the non-contact mode by which no pattern peel occurs. In the initial stage of the tip scan operation, the tip apex is already set apart from the Si(100) substrate slightly in order to prevent the friction of tip apex and the substrate. Subsequently, the tip traversed the dot pattern by moving the piezo stage. (ii): By contacting the tip to the top corner of the pattern, the cantilever was distorted gradually. (Fig.1a) (iii): Then, by directly applying load to the top corner of the resist pattern with the cantilever tip, the pattern adhering on the substrate can be peeled easily (Fig.1b). (iv): Finally,
the pattern peel and residue formation on the Si(100) substrate can be reconfirmed by imaging the sample surface in the non-contact mode with the AFM. Neither the tip apex nor the dot resist pattern appeared to be damaged as a result of the surface scanning procedure by the cantilever tip. The DPAT experiment was carried out in both DI-water and dry air in order to compare each other. The pattern peel in dry atmosphere were carried out at 23 °C, 4 %RH. Details of the peeling investigation and instrumentation are described elsewhere [2, 3].

3. Results and Discussion

Figure 2 shows the AFM images of pattern peel investigation. By applying a certain load with the AFM tip (white arrow), the resist pattern can be peeled easily in both DI water and dry condition.

Table-I Load for pattern peel

<table>
<thead>
<tr>
<th>Environment</th>
<th>Load (μN)</th>
<th>Standard deviation (μN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>In water</td>
<td>4.6</td>
<td>0.78</td>
</tr>
<tr>
<td>In dry air</td>
<td>12.2</td>
<td>1.3</td>
</tr>
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</table>

In both cases, no residue on the Si substrate confirmed after the pattern peel. Therefore, the pattern peel occurs due to interface destruction. Table-I summarizes the load for pattern peel in both cases. The load is slightly deviated, but still is well within the range of experimental scatter. In DI-water, the load for peel is approximately one-third as small as that in dry air. It can safely state that the additional external effect, that is, liquid intrusion which acts to weaken adhesion strength between resist and substrate, should be taken into consideration, as shown in Fig.2.[4]

4. Conclusion

The peeling property of the resist pattern in DI-water can be analyzed by the DPAT method. This technique will prove useful to design and optimize micro-lithography process.

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References